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A previously reported series of sound quality experiments was continued and included an analysis of all data obtained. The tests were conducted to determine the effect of the sound quality of language laboratory equipment on the learning of foreign languages. Attention was focused on the frequency response characteristics of the sound recording and reproducing equipment and their contribution to the recognition aspect of learning. The effects of these characteristics on pronunciation were also studied, but the results were less consistent. Equipment, recordings, and procedures used were discussed. Detailed tables of results are explained.

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LANGUAGE LEARNING AND FREQUENCY RESPONSE II

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Under a grant from the Educational Facilities Laboratories, Inc. a series of tests has been conducted at M.I.T. to determine the effect of the sound quality of language laboratory equipment on the learning of foreign languages. We have focussed our attention on the frequency response characteristics of the sound recording and reproducing equipment and their contribution to the recognition aspect of learning. We also studied the effect of these characteristics on pronunciation, a problem which proved to be more difficult.

We have reported previously on a first set of tests (Experiments I and II) in which the high frequency cut-off characteristic of our equipment was varied in three steps: 3000 cps, 5000 cps, and 7300 cps.* In the present paper we report on a new set of tests (Experiment III) in which the low frequency cut-off characteristic of the sound reproducing system was varied, and we present an analysis of the data obtained in this and the previous set of tests.

In Experiment III the recognition of foreign language phonemic contrasts was tested under conditions in which the frequencies of the sound-reproducing system below 50, 500, and 1000 cps respectively were filtered out before they reached the student. Some attempt was made to analyze the pronunciation scores of the students as well, but this yielded less consistent results.

Equipment

As in the previously described experiment we used M.I.T.'s language laboratory equipped with the Linguatrainer system. The students heard master recordings played on a Viking tape recorder (85 deck, RP61 VU preamplifier, Realistic amplifier) through two variable electronic filters (Spencer-Kennedy Model 302) with 18 db per octave cut-off characteristic, which were cascaded to obtain 36 db per octave cutoff.

Master recordings

The original master recordings were the same as those used in the previous experiments. They were recorded on a Presto C800 recorder using an Altec 21B microphone. The same recordings were played to all the student subjects but through different high pass filter settings: 50, 500, and 1000 cycles. Thus in Experiment III the frequency ranges studied are:

A - 50 cps - 7300 cps
B - 500 cps - 7300 cps
C - 1000 cps - 7300 cps

Frequency response of the system

The frequency characteristic of the entire system was checked prior to the test. We used a tape on which various frequencies were recorded at the same energy level. This tape was played through each student position and the

* "Language Learning and Frequency Response," M. Buka, M. Z. Freeman, W. N. Locke, International Journal of American Linguistics, Part II, Vol. 28, No. 1, January 1962, pp. 62-79.

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energy level was recorded at the headset terminals. For each position the response curves were plotted in terms of db loss (arbitrarily assuming zero db loss at 1000 cps), from 50 cps up and in each case the loss was no more than 3 db at 50 cycles. The frequency response characteristic of the headset at these low frequencies depends largely on the seal between earphone and head. Our Telephonic earphones have rubber cushions, and we made an effort to see that they were placed properly on the students' heads. It is known that for a nearly perfect seal the headset characteristics are flat ± 1 db to about 25 cps. Thus we are able to assume that the filter setting of 50 cps represented the true point of low frequency cut-off of the sound delivered to the group A.

Experimental design

In all 22 phonemic contrasts in German and 23 in French were represented by 90 pairs of words in tests lasting ten minutes each.* These tests were recorded by a male voice in the following manner. First a pair of words illustrating a contrast was pronounced by the native speaker. It was followed by a pause during which the student pronounced both words. Next the speaker repeated one of the two words and the student indicated by a check in the proper column of the answer sheet whether the word repeated had been the first or the second of the original pair. He was scored on the number of correct identifications. (Evaluation of pronunciation is discussed below.)

There were five such tests using the same 90 pairs of words but presenting them in a different order. Random numbers were used for the ordering and for determining which word of the pair was to be repeated. The five tests were administered on five consecutive days.

The following designations will be used below:

The letters G and F will stand for German and French

The numbers 1 to 5 will denote the five tests in the order in which they were administered.

The letters A, B, and C will stand for filter settings.

Thus, G4C means German test 4 high pass filter setting 1000 cps, eliminating all lower frequencies.

Test procedure

Thirty students were selected and divided into groups a, b, c of 10 each.** We placed one group at a time in the booths of the laboratory. The tests were administered in the following sequence:

* See our previous report, op. cit., Figures VIII and IX for tests used.

** Due to absences and dropping out of some of the students we usually had groups smaller than 10. However, to make the averages comparable we normalized all the results to ten per group.

Group	Monday		Tuesday		Wednesday		Thursday		Friday		Monday	
	Ger.	Fr.	Ger.	Fr.	Ger.	Fr.	Ger.	Fr.	Ger.	Fr.	Ger.	Fr.
a	1A*		1C	1B	2C	2B	3C	3B	4C	4B	5C	5B
b		1A	1B	2A	2B	3A	3B	4A	4B	5A	--	--
c	1A		2A	1C	3A	2C	4A	3C	5B 5A	4C		5C

The total scores obtained in this series of experiments are summarized in Table I. A graphic representation of the same scores is given in Figure 1.

RECOGNITION

Analysis

For the sake of simplifying comparison between the results of the earlier Experiment II and the present Experiment III (high and low frequency cut-off respectively) our analysis here follows exactly the same pattern as that used before.

German

1. As can be seen from Table I, the average number of errors for German tests 2,3,4, and 5* is

Filter setting	A (50 cps)	B (500 cps)	C (1000 cps)
Avg. no. of errors per student	10.6	13.8	14.4
% error (based on 90 chances to make an error)	12.9	15.4	16.0

The significance of the difference between these averages was tested by the chi square method. The difference between A and B, as well as A and C, was found to be significant (p = .01). There was no significant difference

* The first day all students got A tests. The first group's German 1A test does not enter into the calculation of averages, since that group later listened only to German C tests.

between B and C. Thus the recognition of German words by our students seemed to have been impaired by the 500 cps high pass filter almost as much as by 1000 cps.

2. Next tabulation was made of the rate of error by phonemic contrasts, as shown in Table II. Of a total of 1609 errors, 1237 or 77% were due to consonant contrasts which constitute only 42% of the items in each test An especially marked effect is seen in the paired contrasts /pt-t/, /s-ts/, and /g-d/. Only two of the vowel contrasts caused consistent difficulty (/y-ø/ and /y-u/), while the remaining 48 vowel contrasting pairs averaged 1.4 errors per item per ten-student group.

Increase of rate of error with the rising of the lower frequency cut-off appears quite consistently throughout the entire German test, for vowel as well as consonant contrasts:

Total number of errors, German tests 2-5

	A (50 cps)	B (500 cps)	C (1000 cps)
Total consonants (38)	360	416	461
Total vowels (52)	81	148	143

French

1. Again from Table I we see

Filter setting	A (50 cps)	B (500 cps)	C (1000 cps)
Avg. no. of errors per student	15.2	16.6	16.6
% error (based on 90 chances to make an error)	16.9	18.5	18.5

These overall averages were tested by the chi square method and found not to be significant.

2. Table III shows a breakdown for the errors in the French tests by phonemic contrasts. We may see from this table that the relation between the number of errors due to vowel contrasts and that due to consonant contrasts differs considerably between French and German. Whereas in German most of the errors seem caused by consonant contrasts, in French the vowel contrasts contribute equally to the totals. The following pairs of phonemic contrasts appear to reflect the effects of degrading the system: /l-n/,/dR-R/, /R-l/, /g-d/, /±R/ and /ɛ̃-œ̃/, /ɔ̃-ɑ̃/, /e - ɛ/. We shall relate these findings to the previous experiment before drawing any conclusions.

Comparison between Experiment II and Experiment III

As was mentioned earlier the general setup of both experiments was the same, the only difference being the low pass filtering in the earlier experiment and high pass filtering in the present experiment. The non-filtered groups (A) in both experiments have full frequency range (50 - 7300 cps) and are therefore exactly comparable.

The average percentage of errors in these A groups were:

	French	German
Exp. II	14.2	11.1
Exp. III	16.9	12.2

It seemed worthwhile to analyze the difference between each pair of 'A' scores to get a better measure of the possible range of test scores with a greater number of test participants.

1. Variability in the number of errors

German

The total number of errors for each of the 90 items in five German tests of group A (non-filtered) was tabulated for Experiment II and Experiment III. This number was based on 42 tries in each experiment (i.e., 8 or 9 students, 5 tests). Then the difference between the number of errors in Experiments II and III was tabulated. The frequency distribution of these differences is plotted in Figure 2. Thus this curve shows how many times the number of errors for a given item was the same in both experiments, greater by 1,2,3, etc., or smaller by 1,2,3, etc.

We see from this that the two series of German tests show great conformity. In 29 out of items the scores were exactly the same, in another third of the items the scores varied by no more than plus or minus one and two; the greatest differences which occurred amounted to plus seven and minus six.

French

The corresponding tabulation of differences was made for the French tests. This time, as was to be expected from the far greater difference between the overall averages, the distribution of the differences (also plotted in Fig. 2) shows a much smaller degree of conformity between the individual item scores in the two Experiments. We know of no factor either in the make-up of the student groups or in the administration of the two series of tests that might account for the fact that the German tests showed so much less variation between experiments than did the French tests. We shall, therefore, assume that the real range of error variation is greater in our French than in our German tests, and we shall consider that performance under the condition of an unfiltered system is best represented by the combination of our scores from both experiments.

2. Order of difficulty

We shall define "order of difficulty" as the order of phonemic contrasts when arranged according to the number of errors in recognition made by the students First we grouped all items by phonemic contrasts and tabulated the total number of errors made in each contrast in both non-filtered experiments. Since the number of items representing each phonemic contrast was different, we computed the average number of errors per item (i.e., divided the total number of errors for each contrast group by the number of items in each group, and then recorded it as a percentage of the total number of tries. We then arranged these contrasts in order of decreasing difficulty.

Table IV presents the percentage of errors in recognition from all tests for all students in Experiment II and III under each filtering condition in order of difficulty of phonemic contrasts.

The following observations can be made on the basis of this tabulation.

1. In German, almost all difficult phonemic contrasts suffer from any degradation of the system. However, they suffer to a different degree and the point on the frequency scale at which they are affected varies. For some contrasts a marked increase in difficulty occurs between conditions A and B; and for some, between B and C. The one exception is vowel contrast 2 /u-y/ represented in the tests by a single item which makes this score less reliable than others.

2. In French the picture is much less clear (consistent with our observation of greater variability in the French test scores) but essentially the same holds true: the majority of consonant contrasts suffers in varying amounts from any degradation of the system. All consonant contrasts of order of difficulty from 1 to 7 (all those with more than 11% error in the reference group) except 5 show a clear pattern of increasing number of errors as the low frequency cutoff is raised. Less difficult contrasts were affected more by a 500 cps filter than by 1000 cps. All the more difficult vowels (contrasts 1 to 5) also were adversely affected by the raising of the low frequency cutoff from 50 to 1000 cps, though for some of them the number of errors decreased between 50 and 500 cps. One exception to this was again contrast 4, /y-u/ which is the same that showed a reverse trend in the German tests.

3. Since the rate of increase in recognition difficulty varies for different contrasts their relative difficulty may change with the degrading of the system. We will label the consonant and vowel phonemic contrasts 1,2,3, etc. according to increasing order of difficulty as found in the reference group A (unfiltered). Rearranging the contrasts in the order of difficulty found with the most degraded systems (C) in both experiments, we get:

	Consonants	Vowels
German		
Exp. II & III (50-7300 cps)	1 2 3 4 5 6 7	1 2 3 4 5
Exp. II (1000-7300 cps)	3 2 1 5 6 4 7	1 2 3 4 5
Exp. III (50-3000 cps)	3 1 2 5 4 7 6	1 2 3 5 4
French		
Exp. II & III (50-7300 cps)	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9
Exp. II (1000-7300 cps)	1 2 4 6 7 3 10 5 9 11 8 12	1 2 3 4 6 5 8 7 9
Exp. III (50-3000 cps)	1 2 4 3 7 6 10 5 9 11 8 12	1 2 3 4 5 6 7 8 9

Here we notice first, that in every instance the order of difficulty changes for consonants, but not for vowels, indicating that consonants are differently affected by filtering; second, that the change of the relative order of difficulty is almost the same for low or high frequency cutoff.

PRONUNCIATION

Learning curves

Figure 1 shows the "learning curves," i.e., the progress made by each group in Experiment III from test 1 to test 5. The dotted lines under French A and German A represent the averages derived from A groups in Experiment II and III combined, which we feel constitute a meaningful base line against which to compare the results obtained under the filtered conditions.

Since each point on these curves represents the result of only one test, i.e., the average of a maximum of 10 individual scores, we do not feel that any firm conclusions can be drawn from them. They are at best indicative.

In each language A, B, and C groups listened to the same recording of each test but through different filters. Thus there may have been individual differences between the tests themselves that could have overshadowing influence on the scores. To be free of this type of bias a number of different recordings could be used.

Recordings of the students' oral performance during the tests were available for analysis. In both experiments and both languages the first, third, and fifth tests of every participating student were recorded on tapes to permit further study. These recordings were five minutes in length (each representing half the length of the corresponding ten-minute test), and contained the recorded voice of the native speaker and the students' repetition of each pair of word contrasts, under the various frequency cutoff conditions. Roughly 45 word pairs were recorded on each five-minute tape. Pronunciation was scored in the following manner: a total score number was obtained to represent each paired item by rating the quality and comprehensibility of each member of the pair, with special emphasis on the contrast which was being illustrated in each instance. Two listeners were used, one scoring all the French tests and the other all the German tests. Even though agreement had been reached on the overall principles of scoring, effects of individual differences in approach and emphasis between the two listeners appear in the scores. The range of possible scores for a given paired item was from 0 to 4.

The pronunciation scores (average per item) were grouped by contrasts and are tabulated in Table V in order of decreasing difficulty as established by the recognition tests. The number of occurrences for each contrast was different, because different five-minute portions of the ten-minute test were recorded. The data show great variability and, as some of the contrasts had few occurrences, no very reliable averages were obtained. However, a general remark may be made that in German the non-filtered reference group A shows essentially the same order of difficulty as was obtained by the recognition tests.

In Table VI the average scores per student in both experiments were tabulated. Here we can observe a slight but persistent correspondence between the frequency cutoff and the pronunciation scores. In German Experiment II this is entirely due to consonants while in German Experiment III the vowels also contribute to the improvement of the score as the sound quality of the system improves. The picture is less clear in French. We notice, however, an improvement in the scores from the first to the fifth test and an improvement in consonants in Experiment II as the upper frequency cutoff is raised.

No statistical analysis was performed on this data, because it was found to have great variability and because the total number of observations was too small.

One consideration which had not been taken into account when this part of the experiment was planned was later felt to have played a rather important role in regard to the scoring of the students' pronunciation. When listening to recordings of tests produced under conditions of increasing degradation of the system, it becomes progressively more difficult for the listener to compare the students' performance with an ideal standard. Instead it would seem that he tends to relate a performance produced under condition C to the deteriorated standard of the native speaker on the master tape recording under this same condition. In this connection it might be worth noting that the listener who scored the French tests felt that in many instances the degrading of the system tended to make the nasal vowels more accessible to the students' imitative attempts, while only very few sounds had become indistinguishable.

Conclusion

The difficulty of recognition of unfamiliar phonemic contrasts seems to increase with high or low frequency limitation. This increase in difficulty is not the same for all phonemic contrasts, but the contrasts are affected in the same manner by either limitation. Consonants are affected more, and German shows a much clearer picture than French.

The pronunciation scores on the whole support the conclusions from the recognition scores.

January 23, 1962

TABLE I

NUMBER OF ERRORS MADE IN EXPERIMENT III IN FRENCH AND GERMAN TESTS 1 TO 5

		Frequency Group								
		A			B			C		
Lang.	Test No.	No. of students	No. of errors	Avg.	No. of students	No. of errors	Avg.	No. of students	No. of errors	Avg.
GERMAN	1	9	111	12.4	10	163	16.3	*		
	2	8	99	12.4	10	144	14.4	10	148	14.8
	3	9	84	9.1	10	132	13.2	8	98	12.2
	4	8	93	11.6	8	107	13.4	10	139	13.9
	5	8	76	9.5	4	57	14.2	9	113	12.6
	Total tests 2-5	33	352	10.6	32	440	13.8	37	498	14.4
FRENCH	1	10	169	16.9	10	188	18.8	8	145	18.1
	2	10	152	15.2	10	177	17.7	9	141	15.7
	3	10	160	16.0	9	133	14.8	9	125	14.0
	4	10	156	15.6	10	154	15.4	8	130	16.2
	5	8	90	11.2	9	143	15.9	8	156	20.7
	Total	48	727	15.1	48	795	16.6	42	697	16.6
French & German	Total	90	1190	13.2	90	1398	15.5	79	1195	14.9

* German test 1C was given under conditions such that it was felt its results would not be exactly comparable to the scores of German 1A and German 1B. Hence totals include only tests 2-5.

TABLE II

BREAKDOWN OF ERRORS BY PHONEMIC CONTRASTS IN EXPERIMENT III, GERMAN TESTS 2-5*

	Contrasts	No. of items	NUMBER OF ERRORS: Frequency cutoff A(50)	B(500)	C(1000)	Total	Average per item
CONSONANTS	/pf - f/	9	146	162	152	460	17
	/ʃ - c/	7	94	105	98	297	14
	/pt - t/	2	13	16	39	68	11
	/s - ts/	10	60	70	98	228	8
	/kt - χt/	4	27	29	36	92	8
	/g - d/	4	12	25	26	63	5
	/p - k/, /k - t/	2	8	9	12	29	5
	Total consonants	38	360	416	461	1237	11
VOWELS	/y - ø	3	47	50	48	145	16
	/y - u/	1	8	10	6	24	8
	/au - ɔj/	3	2	3	11	16	2
	/aj - ɔj/	7	7	20	10	37	1.8
	Other vowels	38	17	65	68	150	1.3
	Total vowels	52	81	148	143	372	2.4
	Total contrasts	90	441	564	604	1609	6

* The scores of the first tests were omitted as not being exactly comparable. The scores are normalized to 10-student groups.

TABLE III

BREAKDOWN OF ERRORS BY PHONEMIC CONTRASTS IN EXPERIMENT III, FRENCH TESTS 1-5*

	Contrasts	No. of items	Frequency cutoff A(50)	B(500)	C(1000)	Total errors	Average per item
CONSONANTS	/l - n/	1	26	30	37	93	31
	/dR - R/	1	8	18	20	46	15
	/R - l/	7	59	81	92	232	11
	/d - t/	1	8	9	10	27	9
	/g - d/	8	56	70	69	195	8
	/n - ɲ/	4	25	40	33	98	8
	± /R/	4	24	25	37	86	7
	/t - k/	5	28	44	38	110	7
	/s - z/	4	37	19	31	87	7
	/R - n/	5	26	43	30	99	6.5
	/ʃ - ʒ/	7	50	45	35	130	6
	± /l/	1	4	4	1	9	3
	Total consonants	48	351	428	433	1212	84
VOWELS	/ɛ̃ - œ̃/	5	90	101	100	291	19.5
	/ɔ̃ - ɑ̃/	8	122	135	135	392	16
	/e - ɛ/	6	76	70	104	250	14
	/y - u/	6	41	40	39	120	6.5
	/i - y/	5	32	29	20	81	5.5
	/ɑ̃ - œ̃/	6	19	22	13	54	3
	/ɔ - o/	1	3	2	4	9	3
	/o - œ/	1	3	4	1	8	3
	/ø - œ/	4	6	4	4	14	1
	Total vowels	42	392	407	420	1219	96
	Total contrasts	90	743	835	853	2431	9

* Normalized to 10-student groups

TABLE IV

COMPARISON BETWEEN EXPERIMENTS II AND III

Phonemic contrast	Order of difficulty	No.of items	% error in all A tests	Exp. II % errors A(7300)	B(5000)	C(3000)	Exp. III % errors A(50)	B(500)	C(1000)
				German					
Consonants									
/pf - f/	1	9	36.0	39.6	44.6*	42.2	32.4	36.0*	33.6
/ʃ -c/	2	7	26.8	27.0	40.0	43.6	26.8	30.0*	28.0
/pt - t/	3	2	14.6	16.0	20.0	60.0	13.0	16.0	40.0
/kt - χt/	4	4	13.8	14.0*	11.6	17.0	13.4	14.4	18.0
/s - ts/	5	10	12.6	13.2*	10.0	20.4	12.0	14.0	19.6
/p-k/, /k-t/	6	2	9.0	10.0	13.0	18.0	8.0	9.0	12.0
/g - d/	7	3	6.0	6.0	8.6*	6.6	6.0	12.4	13.0
Vowels									
/y - ø/	1	3	32.0	32.6	32.6	35.2	31.2	33.4*	32.0
/u - y/	2	1	15.0	14.0	22.0*	14.0+	16.0	20.0*	12.0+
/au - ɔj/	3	3	5.0	8.6	9.4	14.0	1.4	2.0	7.4
/oj - ɔj/	4	7	3.2	4.2	4.8	13.0	2.0	5.6*	2.8
other	5	38	1.0	1.2	1.6	2.6	.8	3.4	3.6
				French					
Consonants									
/l - n/	1	1	36.0	22.0	52.0	48.0	52.0	60.0	74.0
/dR - R/	2	1	20.0	24.0	28.0*	22.0+	16.0	36.0	40.0
/d - t/	3	1	20.0	24.0*	12.0	12.0+	16.0	18.0	20.0
/R - l/	4	7	14.0	11.4	17.2	18.6	16.8	23.2	26.2
/s - z/	5	4	13.2	8.0	8.6	9.0	18.4*	9.4	15.4+
/g - d/	6	8	13.0	12.0	13.6	13.6	14.0	17.6*	17.2
+ /R/	7	4	12.0	9.0	10.4	13.4	12.0	12.4	18.4
/ʃ - ʒ/	8	7	11.0	7.6	10.0*	6.6+	14.4*	13.0*	10.0+
/t - k/	9	5	10.0	8.4	11.2*	8.8	11.2	17.6*	15.2
/n - ɲ/	10	4	9.2	6.0	10.4	11.4	12.4	20.0*	16.4
/R - n/	11	5	8.0	5.2	7.2	8.0	10.4	17.2*	12.0
± /l/	12	1	4.0	0	8.0*	2.0	8.0	8.0*	2.0+
Vowels									
/õ - ɔ̃e/	1	5	34.0	31.2	36.8*	29.6+	36.0	40.4*	40.0
/ɔ̃ - ɑ̃/	2	8	30.0	29.6	34.2*	27.0+	30.6	33.8	33.8
/e - ɛ/	3	6	22.8	20.2	26.4*	16.6+	25.2*	23.4	34.8
/y - u/	4	6	17.4	21.0*	16.6*	13.6+	13.6*	13.4*	11.6+
/oe - o/	5	1	12.0	12.0	16.0*	6.0	6.0*	4.0	8.0
/i - y/	6	5	9.0	5.2	13.2*	8.8	12.8*	11.6*	8.0+
/ɑ̃ - œ̃/	7	6	5.2	4.0	9.0*	1.6+	5.6	7.4*	4.4+
/ɔ - o/	8	1	3.0	0	2.0	2.0	6.0	8.0*	2.0+
/ø - oe/	9	4	2.2	1.5*	1.0*	0	5.0*	2.0	2.0

* indicates decrease in percentage of errors between groups

+ indicates overall decrease in errors from A to C

TABLE V*

AVERAGE PRONUNCIATION SCORES

German

Phonemic contrast	Order of difficulty	All A tests No. of tries	All A tests Avg. scores	Experiment II A Tries	Experiment II A Mean	Experiment II B Tries	Experiment II B Mean	Experiment II C Tries	Experiment II C Mean	Experiment III A Tries	Experiment III A Mean	Experiment III B Tries	Experiment III B Mean	Experiment III C Tries	Experiment III C Mean
Consonants															
/pf - f/	1	124	1.1	54	1.7	84	.9	87	1.0	70	.6	50	1.2	95	.5
/ʃ - c/	2	79	1.7	35	1.9	43	.6	61	.6	44	1.3	41	.7	68	1.0
/pt - t/	3	4	4.0	4	4.0	8	2.2	8	1.5	--	--	8	2.5	--	--
/kt - χt/	4	32	2.6	18	2.9	24	3.0	43	2.4	14	2.2	22	2.2	25	1.7
/s - ts/	5	129	3.3	50	3.3	82	3.2	99	2.9	79	3.3	68	3.2	107	3.4
/p-k/, /k-t/	6	14	2.9	8	3.2	8	3.0	8	2.5	6	2.5	8	3.0	--	--
/g - d/	7	18	3.8	2	4.0	9	4.0	7	3.4	16	3.8	4	4.0	18	4.0
Vowels															
/y - ø/	1	20	2.2	4	3.0	14	2.6	11	1.8	16	1.9	8	2.1	18	1.7
/u - y/	2	10	1.5	2	0	5	1.2	4	3.0	8	1.9	4	2.0	9	2.0
/au - ɔj/	3	22	2.7	8	2.2	9	2.9	11	3.1	14	2.9	11	3.1	18	3.2
/oj - ɔj/	4	63	3.6	22	3.6	18	3.7	18	3.7	41	3.5	18	3.2	36	3.7
other	5	359	3.4	162	3.5	176	3.5	226	3.6	197	3.2	158	3.2	276	3.1

*Table V continued on next page

TABLE V (Cont.)

AVERAGE PRONUNCIATION SCORES

French

Phonemic contrast	Order of difficulty	All A tests No.of tries	All A tests Avg.scores	Experiment II A Tries	A Mean	B Tries	B Mean	C Tries	C Mean	Experiment III A Tries	A Mean	B Tries	B Mean	C Tries	C Mean
Consonants															
/l - n/	1	27	1.8	11	1.7	10	2.5	11	1.7	11	2.2	16	2.8	14	1.8
/dR - R/	2	33	3.6	11	3.5	13	3.7	11	3.2	14	3.5	19	3.6	7	3.0
/d - t/	3	6	2.8	--	--	--	--	--	--	6	2.8	6	2.5	--	--
/R - l/	4	107	3.2	33	3.2	31	3.4	36	3.2	51	3.0	61	3.4	35	3.4
/s - z/	5	83	3.2	27	3.4	27.	3.4	33	3.0	34	3.3	39	3.5	6	3.5
/g - d/	6	127	3.3	55	3.6	55	3.4	55	3.3	45	3.5	73	3.4	70	3.3
+ /R/	7	22	3.8	16	3.9	16	3.4	16	3.4	6	3.5	22	3.1	14	3.9
/ʃ -ʒ/	8	104	3.8	52	3.6	53	3.5	44	3.3	38	3.9	77	3.6	46	3.3
/t - k/	9	96	3.5	28	3.7	24	3.4	30	3.3	46	3.5	57	3.3	35	3.1
/n - ɲ/	10	39	3.6	11	3.8	10	3.5	11	2.9	20	3.7	22	3.8	13	3.2
/R - n/	11	44	3.1	26	3.0	25	3.0	22	3.0	18	3.3	43	3.4	7	3.1
± /l/	12	19	3.9	3	4.0	3	3.3	3	1.7	8	3.9	3	3.3	7	2.7
Vowels															
/õ - œ̃/	1	95	3.0	37	2.9	37	3.0	40	2.9	35	3.2	49	3.2	27	3.1
/ɔ̃ - ɑ̃/	2	182	3.7	60	3.2	57	3.4	68	3.2	76	3.9	87	3.5	46	3.3
/e - ɛ/	3	116	3.2	41	3.5	41	3.1	50	3.2	43	2.7	53	3.1	34	3.2
/y - u/	4	64	3.5	26	3.0	33	2.2	11	2.7	32	3.5	57	2.6	21	3.3
/oe - o/	5	14	3.7	8	3.6	8	3.6	8	2.9	6	3.9	14	3.8	4	3.8
/i - y/	6	70	3.2	22	3.5	22	3.5	22	3.0	33	3.3	40	3.7	7	3.7
/ɑ̃ - œ̃/	7	110	3.2	52	3.3	50	3.2	49	3.4	38	3.2	68	3.2	31	2.8
/ɔ - o/	8	0	--	--	--	--	--	--	--	--	--	--	--	--	--
/ø - oe/	9	63	3.5	27	3.4	25	3.2	19	3.3	24	3.6	37	3.5	28	3.1

TABLE VI

AVERAGE PRONUNCIATION SCORES

German

Frequency Group	Experiment II	Consonants	Vowels	Total	Experiment III	Consonants	Vowels	Total
A	Test 1	2.4	3.4	3.0	Test 1	1.7	3.0	2.5
	Test 5	2.8	3.3	3.0	Test 5	2.3	3.3	2.8
	All A	2.5	3.4	3.0	All A	2.0	3.2	2.7
B	Test 1	2.0	3.5	2.7	Test 1	1.7	3.1	2.4
	Test 5	2.3	3.3	2.9	Test 5	2.6	3.3	2.9
	All B	2.1	3.4	2.8	All B	2.1	3.1	2.6
C	Test 1	1.4	3.5	2.4	Test 1	1.6	2.9	2.3
	Test 5	2.6	3.5	3.1	Test 5	2.2	3.3	2.8
	All C	1.8	3.5	2.6	All C	1.9	3.1	2.5

French

Frequency Group	Experiment II	Consonants	Vowels	Total	Experiment III	Consonants	Vowels	Total
A	Test 1	2.9	2.7	2.8	Test 1	3.2	3.4	3.3
	Test 5	3.6	3.5	3.5	Test 3*	3.6	3.5	3.6
	All A	3.4	3.2	3.3	All A	3.4	3.4	3.4
B	Test 1	3.0	2.6	2.9	Test 1	3.1	2.7	3.0
	Test 5	3.4	3.4	3.4	Test 3*	3.6	3.5	3.5
	All B	3.3	3.2	3.3	All B	3.4	3.1	3.3
C	Test 1	2.4	2.9	2.7	Test 1	2.9	3.2	3.1
	Test 5	3.4	3.2	3.3	Test 5	3.5	3.2	3.4
	All C	3.1	3.1	3.1	All C	3.2	3.2	3.2

* No #5 available

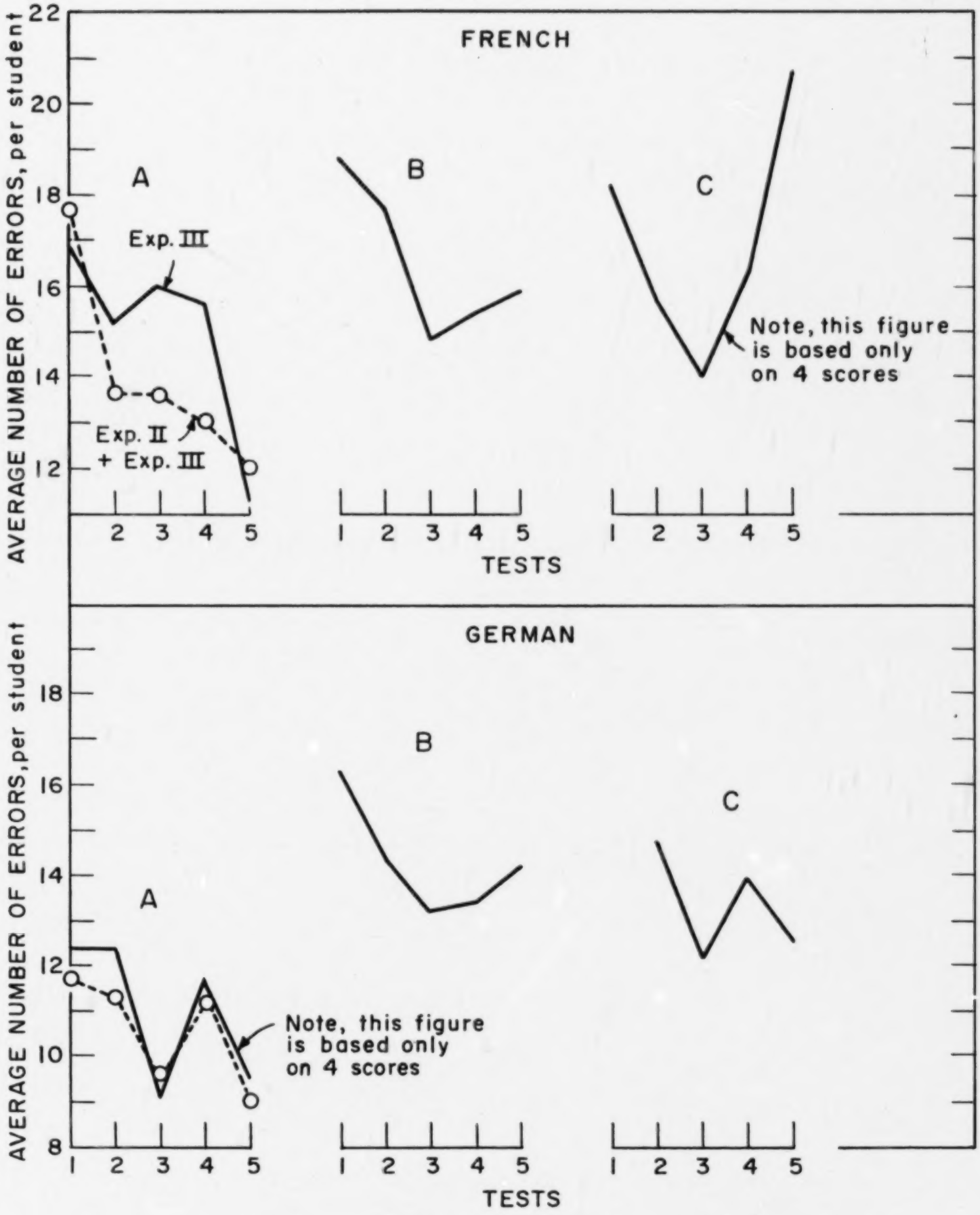


FIG. I LEARNING CURVES FOR FREQUENCY GROUPS A, B, C, EXP. III

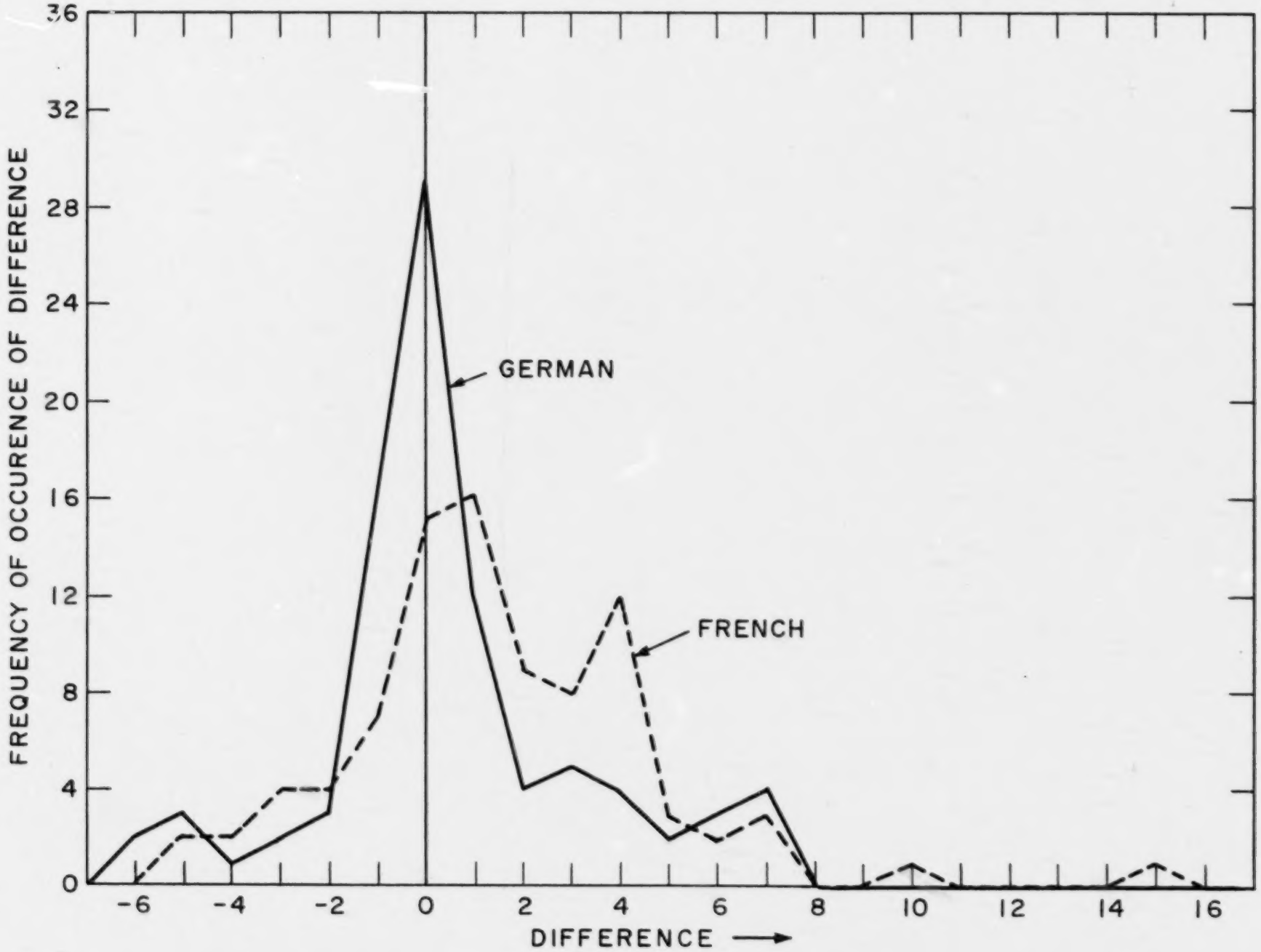
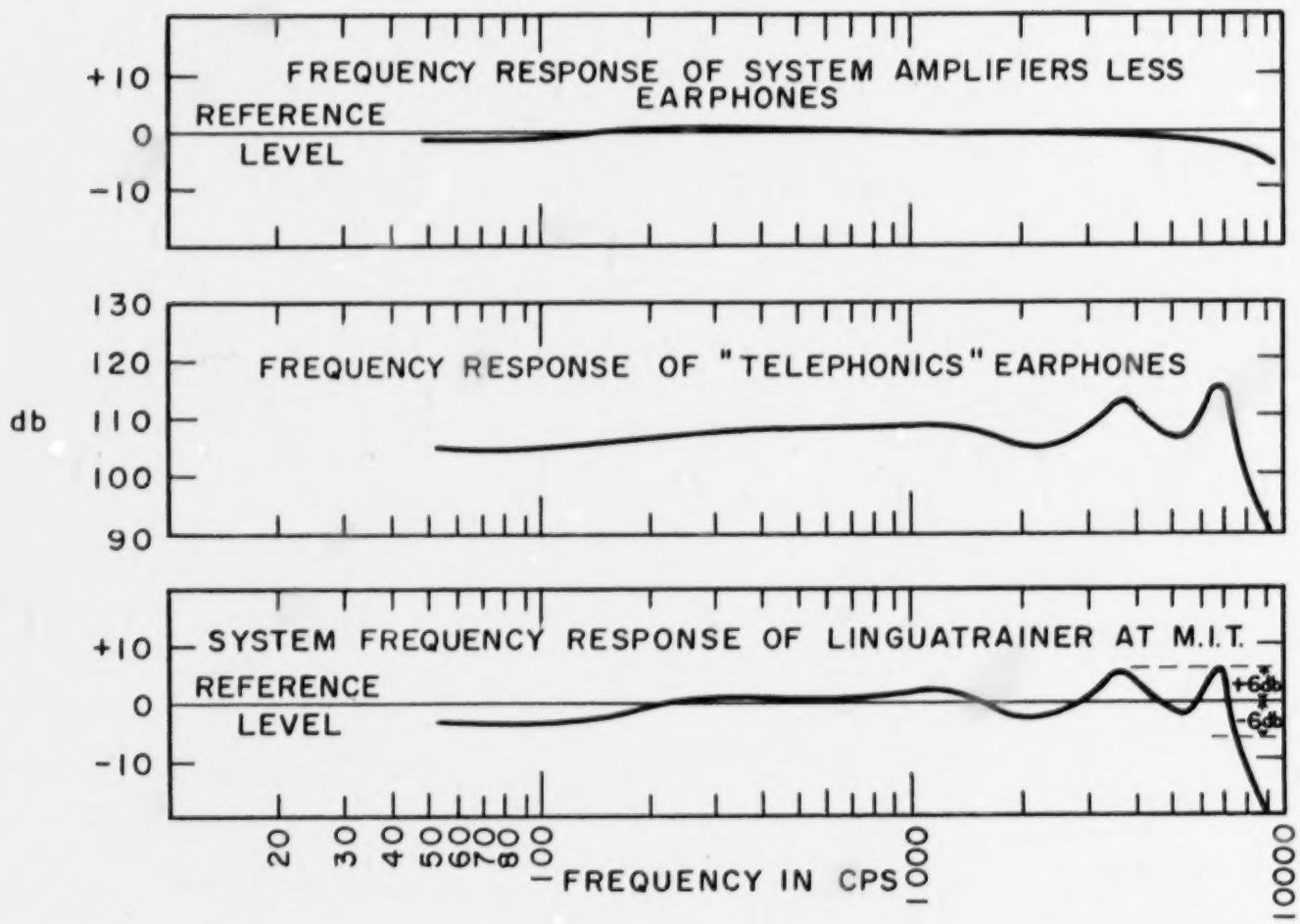


FIG. 2 DISTRIBUTION OF DIFFERENCES BETWEEN THE NUMBER OF ERRORS MADE ON EACH ITEM, EXP. III A MINUS EXP. II A.

SYSTEM FREQUENCY RESPONSE



When an input signal of the same power at all frequencies is introduced into a system, then the system frequency response is the variation in the power of the signal at the output.

The procedure for obtaining the system frequency response consists of making a recording of pure tones of different frequencies but all at the same power level, on the recorder normally used. This recording is played back through the system and the output is read in db on a voltmeter at the headset terminals. A graph of these readings will give the frequency response, excluding the head set. An arbitrary reference level is used in plotting the graph since changing the setting of the amplifier changes the base of the amplifier characteristic; so only the relative differences between power in db at different frequencies are important. This is true only in the normal operating range of the amplifier, not when the amplifiers are overloaded.

To get the system frequency response the earphone characteristic should be determined by a testing laboratory; the apparatus used in obtaining it is quite specialized. The characteristics of the head set then may be added to the first graph algebraically, because in the normal operating range it does not change appreciably with the change of the input power. One may take the highest peak of the phone response, mark this zero, and derive negative numbers for all other points on the curve. These are then added to (subtracted from) the amplifier curve, giving the system response curve.

The graph above illustrates a common situation: the amplifier characteristic is nearly flat and the dominating component of the final curve is the frequency response of the earphones.